DYNAMIC LANDSCAPES AT HIGH LATITUDES ON MARS: CONSTRAINTS FROM POPULATIONS OF SMALL CRATERS. ***M. A. Kreslavsky*** Earth and Planetary Sciences, University of California - Santa Cruz, 1156 High Street, Santa Cruz, CA, 95064, USA; mkreslav@ucsc.edu

Introduction: Populations of impact craters are widely used in planetary science to study surface ages and the nature of resurfacing. Apparent surface age depends on scale; at smaller scales natural surfaces tend to be younger. High resolution imaging of Mars has revealed that at the scales of decameters and smaller, surprisingly many different terrains are devoid of small craters and hence are extremely young [1]. HiRISE images [2] with their high resolution and dynamic range allow identification of smaller craters and hence quantitative studies of younger crater population. Very young crater populations are thought to be unaffected by distal secondary craters, because they are formed after the most recent secondary-forming impact.

All surface above ~60° latitude in both hemispheres is very young at the small scales. Except polar layered deposits, dunes, residual ices and rare very steep slopes, all surfaces at these latitudes are covered by continuous polygonal patterns [3-5], regardless of geological settings. Here I present a progress report in my study of small crater populations on these terrains.

Production function: To apply quantitative methods to crater populations, one needs to know the production function, that is the size-frequency distribution (SFD) of newly formed craters. For small craters it has not been known: the Neukum-Hartmann production function (NPF) [6] is established for crater diameters $D > 10$ m. To obtain it for smaller diameters, I studied [7] a population of small craters on proximal ejecta of Zunil crater. This population is very young and there is a good chance that it is not affected by secondary craters; crater morphology indicates that obliteration of craters is minor, and the population is close to pure accumulation regime; there is a good coverage with 4 full-resolution HiRISE images. I registered locations and diameters of all craters I could identify in the images, about 5700 craters in the 290 km^2 study area.

Some craters in the population form clusters, which occurs due to break-up of projectiles in the atmosphere [8]. For age estimations, each cluster should be considered as a single impact event. I ran a "clustering" algorithm, which identified clusters and replaces them with "effective" craters. The "clustering" is not 100% reliable; some large clusters may be erroneously identified as a few separate clusters; some craters may happen be too close to each other occasionally. However, estimations showed that the effect of these errors can be neglected.

The SFD of the Zunil population has a sharp roll-over at $D < 4.8$ m. Perhaps, some smaller craters are not recognizable in the rough terrains of Zunil ejecta or have been obliterated. For $D > 4.8$ m the SFD is steep (**Fig.1**); for $D > 10$ m it is statistically indistinguishable from the NPF. Properly formulated statistical tests for spatial randomness and isotropy do not contradict the assumption of accumulation population. Totally ~950 effective craters with D>4.8 m give a good statistics. Thus, comparison of some crater population with Zunil ejecta population can give estimates of the crater retention age with respect to Zunil age T_Z.

Absolute calibration: T_Z can be estimated in two ways, both are highly uncertain.

(1) N(10m) with NPF [6] formally gives T_Z = 190 ka. (N(D) denotes the spatial density of craters larger than D.) This estimation is uncertain on the following reasons. First, application of NPF for these young ages is actually a far extrapolation from 100 Ma to 100 ka time scale. Second, the recalculation of the lunar production function to Mars [6] is accurate only within a factor of 2. Third, in that recalculation, the long-term average Mars orbit eccentricity is used, while currently and within the latest 100s ka the eccentricity is significantly higher than the average, and the impact rate should be higher [6].

(2) N(10m) for the new impact craters identified in the images [9] with correction for the spatial non-randomness [10] gives T_Z < 540 ka. This constraint is also a far extrapolation from 10 a to 100 ka time scale. Since the new craters are identified through large dark spots produced by the impacts, we do not know well enough, what area is sensitive, and hence N(10m) is poorly constrained. Then, the total number of new impacts is small and hence, formal statistical uncertainty is large. However, 100 ka or a few 100s ka for T_z are reasonable order-of-magnitude estimates.

Survey: I systematically surveyed 8 full-resolution HiRISE images arbitrary selected in 60°S - 70°S latitude zone. The images were taken in austral summer, after the seasonal frost disappeared. Dunes and steep slopes were excluded; only a typical patterned ground was surveyed, 651 km^2 totally. I identified all features that can be considered as small (D <100 m) craters or results of their degradation (69 objects totally). This identification is highly subjective, and depends on illumination conditions, the presence of boulders, large-scale topography, etc. I tried to distinguish "more certain" (**Fig. 2a,b**; 33 objects) and "less certain" craters; this is also very subjective. SFD for both all objects and "more certain" craterforms (**Fig. 1**) are much gentler than the production function. Among "more certain" objects, 19 are rather sharp depression (**Fig. 2a**), while the rest are much smoother and look mantled (**Fig. 2b**). Identification of sharp depressions is more objective. Their SFD (**Fig. 1**) is steep and perfectly fits the production function at 0.013 T_Z.

Similar survey in the northern high latitudes is ongoing. Preliminary, the total density of craterforms there is significantly lower; so far I haven't found any sharp depression.

Results: (1) There are no pristine craters in the survey area. This gives the formal upper limit for the pristine crater retention age of 0.0012 T_Z (90% confidence). Craters lose their pristine appearance at a time scale of hundreds of years or shorter. Crater modification is an active, ongoing process.

(2) The gentle SFD for craterforms indicates active ongoing process of crater removal. The formal mean crater retention age for 5 m < D < 10 m is within 0.008 - 0.015 T_Z (90% confidence interval). Given the very subjective identification of the craterforms, this estimate actually gives only the order of magnitude. Thus, the characteristic time scale of crater degradation and removal is on the order of thousands of years.

(3) The steep SFD for sharp features may indicate some resurfacing event (mantle emplacement?), which occurred 0.008 - 0.015 T_Z ago (90% confidence interval). This age estimate (roughly 1-3 ka) is too young to attribute this event to some climatic effects caused by astronomical climate forcing, unless we significantly overestimate the impact rate. Additional observations are needed to add certainty to these conclusions.

(4) Preliminary, the resurfacing rates in the northern high latitudes (Phoenix landing site) seem to be higher, or the most recent resurfacing events more recent, than in the southern hemisphere.

Discussion: These results indicate that the landscape at high latitudes is very dynamic; the observed crater degradation rates imply local material displacement on the order of millimeters or centimeters per martian year. On the Earth, the permafrost surface is very dynamic due to the presence of the active layer, a layer experiencing the seasonal freeze - thaw cycle. On Mars, such a cycle and such a layer are absent. Probably, some mechanisms in addition to seasonal thermal contraction and expansion should work; possible candidate mechanisms may involve: unusual microphysics of martian soils; deposition of icy mantles; quick sublimation of shallow subsurface ice, which is out of equilibrium with the atmospheric water vapor, etc. The steep SFD for the sharp craters may argue for mantle deposition, but better crater statistics is needed for robust conclusions. Characteristic time scale of significant crater alteration is smaller than the shortest time scale of spin/orbit-induced climate variations; thus, the dynamic surface processes should occur under the present climate conditions, or, if any climate change is involved, under the present insolation regime.

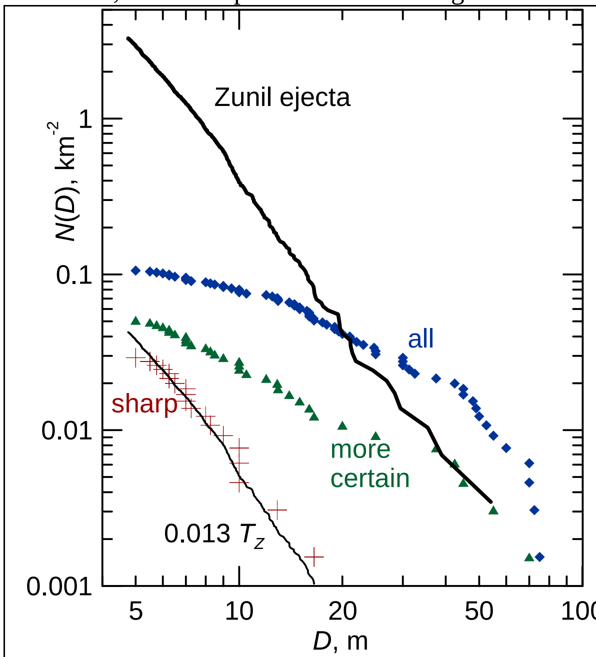

Fig. 1. Size-frequency distributions.

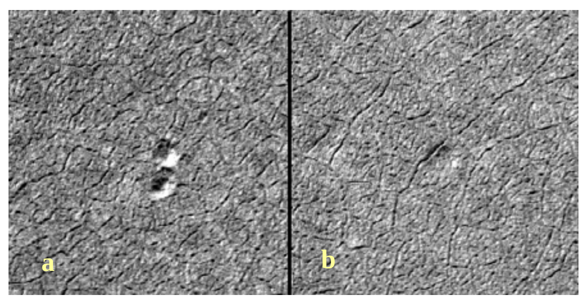

Fig. 2. Typical examples of craterforms in the survey: **(a)** a pair of sharp depressions, presumably craters disrupting the patterned mantle; **(b)** a smooth depression, presumably a mantled crater. From HiRISE image PSP_004116_1130, illuminated from upper left, each scene is 100 × 100 m.

References: [1] Malin M. and Edgett K. (2001) *JGR 106*, 23429. [2] McEwen A. et al. (2007) *JGR 112*, E05S02. [3] Mangold N. (2005) *Icarus 174*, 336. [4] Kostama V.-P. et al. (2006) *GRL 33*, L11201. [5] Mellon M. et al. (2008) *JGR 113*, E00A23. [6] Ivanov B. (2001) *Space Sci. Rev.*, *96*, 87-104. [7] Kreslavsky M. (2008) *Fall AGU meeting*, #P41B-1361. [8] Ivanov, B. et al. (2008) *LPS XXXIX*, #1221. [9] Malin, M. et al. (2006) *Science*, *314*, 1573-1577. [10] Kreslavsky, M. (2007) *7th Mars Conf.*, #3325.